THE ROOTING RESPONSE OF SELECTED PLANTS AS INFLUENCED BY LIGHT QUALITY AND ROOTING MEDIUMS

By

HUGH KENNETH HEDGER

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Oklahoma State University

Stillwater, Oklahoma

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Thesis Approved:

Robert P. Ealy
Thesis Adviser

Samuel C Wiggans

Robert MacVicar
Dean of the Graduate School

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CHAPTER I

INTRODUCTION

For over one hundred fifty years glass has been used as a cover for greenhouses. It is a rather expensive material, however, and subject to destruction by storms and vandalism. This has caused the greenhouse operator to look for other materials to replace glass and thus reduce the maintenance and insurance costs.

Most of the new materials developed as glass replacements have been rejected for general use on greenhouses as unsuitable or uneconomical. Among the first materials used as glass substitutes on small structures such as plant beds and temporary greenhouses was a wide mesh wire screen covered with a transparent cellophane type of material. This became brittle and usually did not last too long. After World War II polyethylene plastics were produced in such quantities as to make them economical for use in covering plant beds and temporary greenhouses. These materials were satisfactory for some purposes but could not be used permanently on large greenhouses. Polyethylene sheeting is usually quite thin and may become so torn or damaged by weathering and sunlight that it has to be replaced.

The development of clear plastic-fiberglass panels has introduced a new type of materials for the possible construction of greenhouses. Plastic-fiberglass is semi-rigid and has more strength than glass. Thus it is possible to reduce the amount of framing required for greenhouse construction, and thereby offset the present high cost of the fiberglass.

Since this material was originally produced for industrial purposes it comes in a great variety of colors. Thus, the following questions may arise: (1) Could some other colors be used to advantage over the clear (transluscent) material? (2) What will be the effect of light transmitted through these colors on rooting, growth, and flowering of various plants?

A study was conducted in the Horticulture Department greenhouses at Oklahoma State University from January to July 1959 by Dr. Robert P. Ealy, Dr. Samuel C. Wiggans and Professor Richard N. Payne using various colored cellophane as light filters on frames over plant propagation benches. Their results indicated that certain colors of light seemed to be more favorable for the rooting of cuttings than others. The colored cellophane tended to fade, however, under high light intensities and was too fragile to be used in greenhouse construction or to cover existing propagation beds satisfactorily. Thus it became necessary to secure a more permanent type of light filter for future studies.

Reducing the time necessary for the rooting of cuttings and developing a better root system in a shorter time is an important phase of the propagation process. The reduction of time in the rooting of plants generally reduces the per cent of loss in the cuttings stuck. This then increases the possibility of greater profits for the nurseryman and florist.

The purpose of the research presented here was to explore some of the possibilities of increasing the efficiency of plant propagation. This paper presents the results obtained and discusses the effect of sunlight transmitted through different colors of fiberglass, with and without supplemental light, upon the rooting of a selected group of cuttings grown in four rooting mediums.

CHAPTER II

REVIEW OF LITERATURE

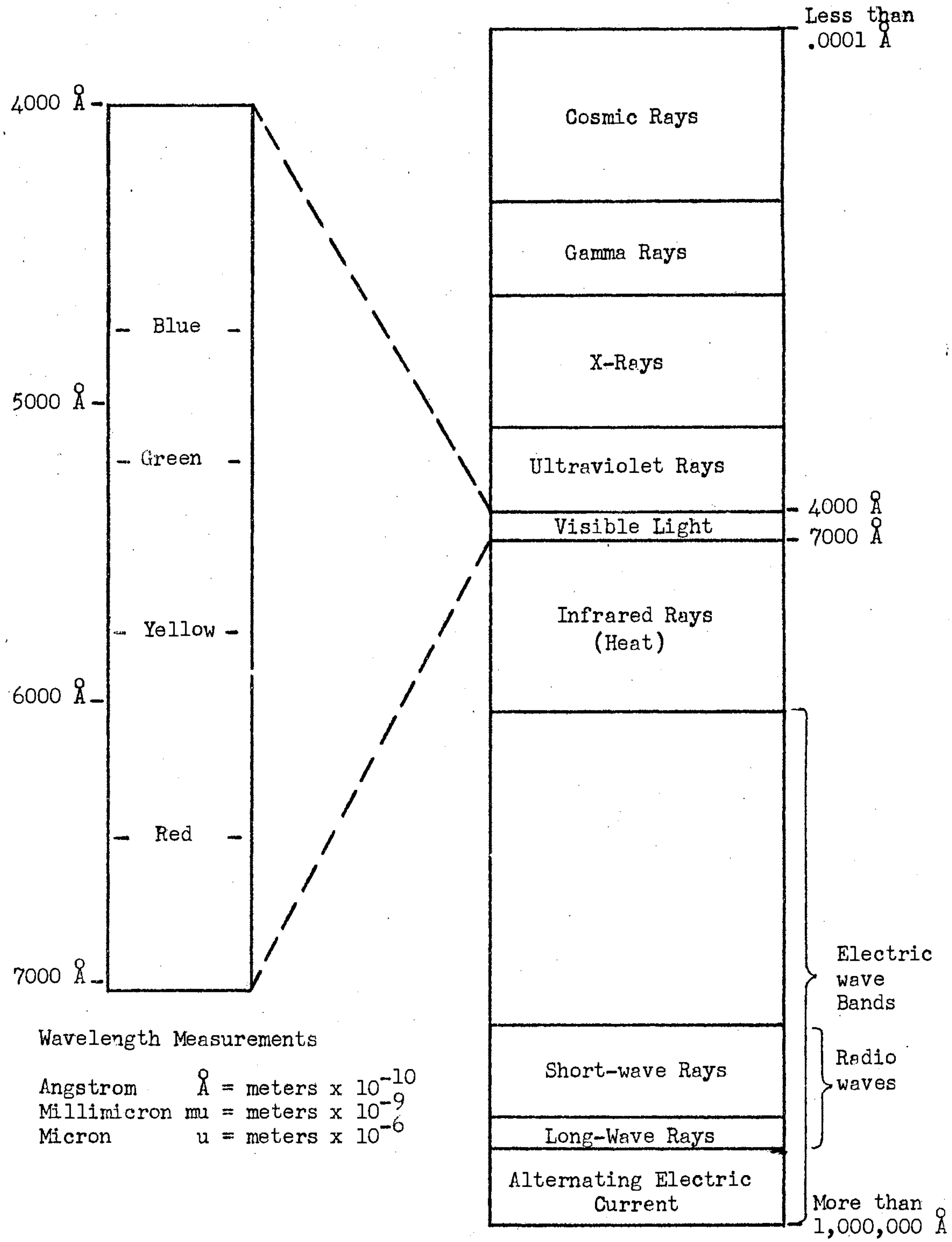
The rooting of cuttings is one of the more expensive tasks of the nurseryman and greenhouse operator. With the rising demand for ornamental plants, caused by a greater number of people purchasing their own homes, the demands for improved efficiency have been greatly increased. Hull, in 1956 (28), showed that much of this demand has also developed from the "Plant America" movement initiated by the American Association of Nurserymen. As the demand for planting materials has become greater, propagators have searched for more and better methods of speeding up the rooting process, increasing the per cent of cuttings rooted, and producing a better root system.

Light, water, temperature and rooting medium, all essential factors for good plant growth, are relatively easy to control with proper equipment. This review of literature covers briefly some of the light theories and the effects of photosynthesis, daylength, light quality, rooting mediums, and the use of water mist for plant propagation.

The presence of light has generally been accepted as a natural phenomenon with little or no thought given to the necessity for light. In recent decades human curiosity has resulted in an increasing interest in light and its actions on plant growth. Since Noah the dispersion of light has been a familiar sight because of the rainbow phenomenon. Newton in 1667 (38) was the first to demonstrate that the same phenomenon could be accomplished by passing light through a prism. This rainbow effect, either natural or with a prism, is an orderly separation of the light waves of the visible portion of the spectrum. Beyond the visible red are the infra-red (heat) and electric wavelengths including the radio transmission waves (Fig. 1). Wavelengths shorter than the visible blue and blueviolet waves include ultra-violet waves, X-rays, gamma (radium) rays, and cosmic rays. Wavelengths may range from more than 1 kilometer in length for electric waves to less than 0.0001 mu (millimicron) for cosmic ray waves. Of the almost interminable range of wavelengths this review is concerned only with the action of a very narrow band of visible light which exerts the greatest influence on plants and which can be distinguished by the human eye.

Light quality refers to the wavelength or portion of the spectrum involved. Van der Veen and Meijer (51) suggested, in a proposal by the Committee for Plant Irradiation in the Netherlands, that the visible and near visible spectrum should be divided into eight wave bands, each of which has a specific physiological effect on the plant:

1. There is no specific effect resulting from irradiation of wavelengths above 10,000 Å (Ångstrom units).
2. In the region between 10,000 and 7000 Å is included radiation having a specific elongating effect on plants.
3. The zone of maximum chlorophyll absorption, maximum photosynthetic activity, and night-break effect is between 7000 and 6000 Å.
4. Between 6100 and 5100 Å the effect is reduced photosynthesis and reduced formative influences, for most plants.
5. The second zone of rather intense activity is between 5100 and 4000 Å where the yellow pigments absorb light which induce



Wavelength Measurements

Angstrom Å = meters x 10^{-10}
Millimicron mu = meters x 10^{-9}
Micron u = meters x 10^{-6}

Figure 1. Spectrum with the visible range extended.

phototropism, protoplasm streaming, and chloroplast movement, also a second peak of chlorophyll absorption.

6. In the zone between 4000 and 3150 Å the formative affect is one in which the plants are shorter and the leaves thicker. This zone may also be known as ultra-violet A.
7. A detrimental zone of irradiation to plants is in the ultra-violet B, or 3150 to 2800 Å wavelength zone.
8. Ultra-violet C, wavelengths shorter than 280 Å, will kill plants rapidly.

Van der Veen and Meijer (51) also suggested that a more logical area for zone 1 would be to include wavelengths of 7000 to 8000 Å, a band that would still include the area of elongation and germination effect.

There are several pigments in plants which depend upon light for their actions. Probably the most important reaction of a plant to light is that which is brought about through its effect on the chlorophyll pigment. According to Strain (49) there are four chlorophylls in the plant kingdom. These include the two green chlorophylls (a and b), brown chlorophyll (c), and red chlorophyll (d). Chlorophylls a and b predominate in the higher plants. All chlorophylls possess the property of fluorescence (34) which is caused by the absorption of light followed by the reradiation of certain light waves. The zone of greatest absorption of light by chlorophyll a and b was shown by Zscheile and Comar (61) to be in the blue-violet region with a secondary maximum in the near red region.

The intensity of light effective in inducing chlorophyll snythesis is relatively low. Shirley (42) found a number of species of plants in which the chlorophyll content per unit leaf weight increased with decreasing light intensity until a relatively low intensity was reached. The synthesis of certain compounds within plants is the result of light reacting upon pigments to supply energy for chlorophyll in its role in photosynthesis. The activation of each pigment is dependent not only on its own absorption spectrum, but also on the absorption characteristics of surrounding pigments.

Light also has a considerable influence on the rate of growth of a plant. Not only does it promote growth but it also may retard growth. According to Maximov (37), the higher the intensity above a certain minimum the greater the retardation.

Some of the early workers, Flint and McAlister (15, 16), found that irradiation from the red area of the spectrum promoted germination of some varieties of lettuce seed while germination was inhibited by infra-red radiation. Borthwick, et al. (6) later verified this and indicated that germination was promoted at 6400 Å (red) and was inhibited at 7200 Å (far-red).

Personnel at the Agricultural Research Station at Beltsville, Maryland, (1) have made intensive studies on the effect of color and intensity of light on plant response. They showed that red light, properly applied, may prevent flowering of some plants, prevent elongation of stems, promote seed germination, and cause color in parts of some plants (red apple color). In each instance the application of far-red light nullifies, or reverses, the action of the red light. These workers discovered what they consider to be the "triggering" mechanism for plant development. The substance involved is apparently a light-sensitive pigment that occurs in two reversible forms. One form absorbs red light while the other absorbs far-red light. Thus, the pigment form produced by the absorption of red light can absorb only far-red light and in absorbing far-red light of sufficient intensity is then converted back to the red-absorbing form. The pigment is a protein that acts as an enzyme. It is known to be blue, since this is the color that is capable of absorbing red light, but it is present in such small quantities that it does not give color to the plants. Borthwick and Hendricks (4) call the pigment "phytochrome" and have designated the red-absorbing form as "P_{660}" and the far-red absorbing form as "P_{730}."

Wassink and Stolwijk (52), Borthwick, et al. (7) and Downs, et al. (13) reported that the radiant energy emitted by incandescent lamps produced excessive elongation of stems.

Hanchey (20) found that fluorescent light of 600 footcandles produced more flowers and fewer leaves in Saintpaulia than 1300 footcandles of natural daylight. He stated that the quality of light from the fluorescent tubes was possibly the influencing factor in the early flowering and quantity of flowering.

Few reports in the literature have indicated that light of a particular wavelength has any great influence on the rooting of cuttings. However, the effect of light on root formation in cuttings has been shown to vary with different cuttings. Christensen (11) found that the use of localized X-ray irradiation on the branches of plants used for cuttings produced more rapid root development in cuttings taken just above the area of irradiation. Audus (2) showed that rooting of Tradescantia cuttings was most effective in wavelengths which were absorbed by chlorophyll. Stoutemyer and Close (46) and Chadwick (10) reported that the red-orange end of the spectrum is more important in the rooting of cuttings than the blue end. Stoutemyer et al. (48)

obtained better rooting response from greenwood cuttings under fluorescent lamps than in natural daylight. Schultz (41) suggested that a combination of incandescent and fluorescent lamps was most effective in rooting of cuttings since incandescent light emits more red than blue, and white fluorescent emits a fair balance of red and blue.

The discovery in 1920 by Garner and Allard (18) of photoperiodism stimulated an increased use of artificial light to extend the number of hours of naturally occuring daylight. By supplying an additional seven hours of 26 footcandles to the existing 10 1/2 hour day Skinner (43) found that he could increase rooting of leaf bud cuttings of Rhododendron. Several workers (31, 44, 48, 53, 55, 57, 58) found that long days, of 12 to 18 hours, gave excellent rooting response for many types of plants, and that in many cases artificial light could supply the entire amount. A photoperiod of 18 to 24 hours on dogwood cuttings produced two to three times as many roots as that of a 9 hour photoperiod (55). Stoutemyer and Close (45, 46) and Zimmerman (60) showed that the photoperiod under which cuttings were rooted had an effect on the initiation of root primordia. Hartman (21) suggests that the greater root formation of leafy cuttings under long photoperiods is due to, or related to, the carbohydrate accumulation. Snyder (44) obtained no benefit from an increase in photoperiod on the rooting Taxus cuspidata. The absence of light which causes etiolation of stem tissues is conducive to the initiation of root primordia in some plants, but leafy cuttings require exposure of the leaves to light for root formation (21). Satisfactory rooting can be obtained with relatively low light intensity (10).

In 1947 Stoutemyer and Close (47) noted that the use of a 16 hour light period of 700 to 800 footcandles illumination on Gordonia axillaris, for 4 to 6 weeks before cuttings were made, produced cuttings which rooted better with less callus than non-illuminated plants. Wassink and Stolwijk (51) showed that the effect of the incandescent filament lamp was probably due to its high emission of red radiant energy which is known to be the most effective portion of the spectrum for photoperiodic control of plants (5). The same spectral regions which most effectively inhibit flowering of short-day plants (5, 8, 39) are the most effective in promoting flowering in long-day plants when used to interrupt the dark period (9). Experiments with different types of lamps have shown that incandescent lamps have a greater efficiency in accelerating the flowering of long-day plants and in promoting rapid vegetative growth of herbaceous and woody plants. However, the fluorescent lamp remains the better source for fulfilling the high intensity light requirements of artificially lighted growth rooms (13).

Most studies using supplemental light to increase photoperiod have been done with reference to vegetative growth and development, or to floral initiation. Avery, et al. (3) suggested that the fundamental principle that governs the differential response of plants to light may be attributed to the effect of light on growth hormones and their indirect effect on the synthesis of carbohydrates. Garner and Allard (19) experimented with the effects of alternating light and dark periods of different lengths on plant growth and development. Kincaid (30) and Crocker (12) discovered that extremely short periods of light were sufficient to trigger the light sensitive pigment of some seeds. Some workers (56, 57) found that a short period of high light intensity in the middle of the dark, on some plants, may effectively replace several hours of long days. Following a nine hour day the application of one hour of light in the middle of the night on dogwood, viburnum and weigela had the same effect as a 15 hour day (55). Recently Waxman (54) reported that on certain plants a long day effect may be obtained by only 16 minutes of light given the plant (one second of light per minute) during a 16 hour period.

The use of plastic coated fiberglass paneling, both flat and corrugated, seems to be a good material to replace glass in the construction of greenhouses. The fiberglass scatters, or diffuses, the light and heat waves (32), therefore modifying the light intensity and spectrum (quality). Little or no shading of fiberglass is required in summer, and it is generally not damaged by hail. In Colorado reports (27) indicate up to 25 per cent better growth of plants under clear white fiberglass than under clear glass. The total dry matter production of carnations during 1959 was: new glass, 100; clear white fiberglass, 118; and coral colored fiberglass, 115. They concluded that plants can efficiently use diffused visible light.

Probably the most important accomplishment aiding in the propagation of plants by cuttings is the development of the intermittent mist system. It has markedly reduced the time necessary for rooting of cuttings. Mahlstede (35) reported that a commercial nurseryman in West DePere, Wisconsin was using mist propagation as early as 1940 with outstanding results for rooting softwood cuttings. Constant mist has not been desirable in most instances since it creates a drainage problem and uses a large volume of water. With intermittent mist, water is applied at frequent but short intervals and comparatively little water is used. This does not lower the temperature of the rooting medium excessively (21). Hess and Snyder (24, 25) showed that there are a number of physiological factors which make the intermittent mist an excellent method for rooting cuttings: (a) the particles of water form a thin layer of moisture on the leaf, which is constantly being evaporated with a resultant absorption of heat and significant cooling effect, (b) water loss from cuttings is reduced, and wilting is prevented, (c) a greater supply of carbohydrates is available for rooting and continuous growth because of the abundance of foliage which may be retained at the time of cutting placement.

The use of intermittent mist is superior to constant mist since there is less leaching of the plant food within the cutting, cuttings can be hardened off more readily when rooted, the drainage problem is greatly reduced, and the disease problem is reduced (25). Hartman and Kester (21) reported that with intermittent mist the temperature of the rooting medium will likely be slightly higher, therefore producing a more favorable rooting situation. They also report that light intensity can be maintained at a higher level on leafy cuttings, thus promoting full photosynthetic activity. By using mist sprays softwood cuttings may be rooted from plants that were previously considered difficult or were impossible to root at certain times during the year.

Hartman and Whisler (32) found that applying intermittent mist only during the day was equal or better than applying mist for longer periods. They also suggested that the "on" and "off" intervals be spaced to allow for thorough wetting of the leaves but to reduce the water used to the absolute minimum.

Many materials and mixtures of materials have been used as rooting mediums for propagation. There are many conflicting reports regarding the best medium for rooting cuttings. Hitchcock (26) tested the rooting of 46 genera of plants and concluded that, under the conditions of his experiment, 90 per cent of the cuttings tested rooted better in a mixture of one part peat and one part sand, by volume, than in either alone. Mahlstede (35) found that cuttings properly handled will root satisfactorily in a wide variety of mediums. For any material to be desirable as a rooting medium it must have a threefold function: (a) provide a method of holding cuttings in place during rooting, (b) supply and hold water, and (c) be sufficiently porous to provide oxygen.

Stoutemyer and Close (45) showed that in order to obtain the best rooting the temperature of the rooting medium should be held slightly above 70° F. Laurie and Ries (33) and Yerkes (59) stated that the rooting should be 8 to 12 degrees warmer than the air. Hartman and Kester (21) found that for the successful rooting of leafy cuttings the air temperature should be from 70° to 80° F. and the temperature of the rooting medium should be near 70° F.

CHAPTER III

MATERIALS AND METHODS

EXPERIMENT A. Started October 31, 1959 and terminated January 18, 1960.

A rigid fiberglass material[1] was obtained in five different colors to be used as filters between sunlight and a greenhouse propagation bench. The greenhouse was constructed of flat, clear (transluscent) fiberglass. Panels of red, amber, pink, green, and yellow fiberglass, each 26 inches wide by 10 feet long were used. The fiberglass was a standard 2 1/2 inch corrugation, approximately 1/16 inch thick, and weighed 6 ounces per square foot. The intensity of the pigmentation was different for each color of fiberglass (Table I).

The fiberglass panels were used as roofs for movable frames (Figures 2, 3) which could be placed over various sections of a propagation bench. The gabled frames were 80 inches long, 40 inches wide, 16 inches high at the sides, and 28 inches high at the peak. The sides of the frames were covered by black polyethylene. A black polyethylene panel also was hung across the center of the frame thereby making two plots within each frame.

Supplemental light was supplied by incandescent bulbs. Light transmitted through the colored fiberglass at night was measured first with 100 watt bulbs placed above the fiberglass covered frames, then adjusted

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[1] Alsynite series 150 furnished by the Alsynite Company of America, San Diego, California.

TABLE I

AVERAGE LIGHT TRANSMISSION OF COLORED FIBERGLASS UNDER CLEAR AND CLOUDY CONDITIONS. READINGS SHOWN IN FOOTCANDLES (FC) AS INDICATED BY THE WESTON SUNLIGHT ILLUMINATION METER, MODEL NO. 756.

	December 1959		February 1960		Transmitted Incandescent Light	
Color of Fiberglass	Clear Days	Cloudy Days	Clear Days	Cloudy Days		
Green	610	540	680	560	4*	16**
Yellow	910	440	950	480	2	14
Pink	720	410	730	450	3	12
Red	110	64	120	68	1	4
Amber	230	110	255	118	3	9
Clear (Check)	2200	1650	2400	1700	10	14

* Readings were taken at night of the light transmitted by 100 watt incandescent bults through colored fiberglass panels.

** Readings after lights were adjusted to obtain 14 fc, as nearly as possible, at the level of the cuttings.

Figure 2. Completed fiberglass hoods in position after sticking the cuttings.

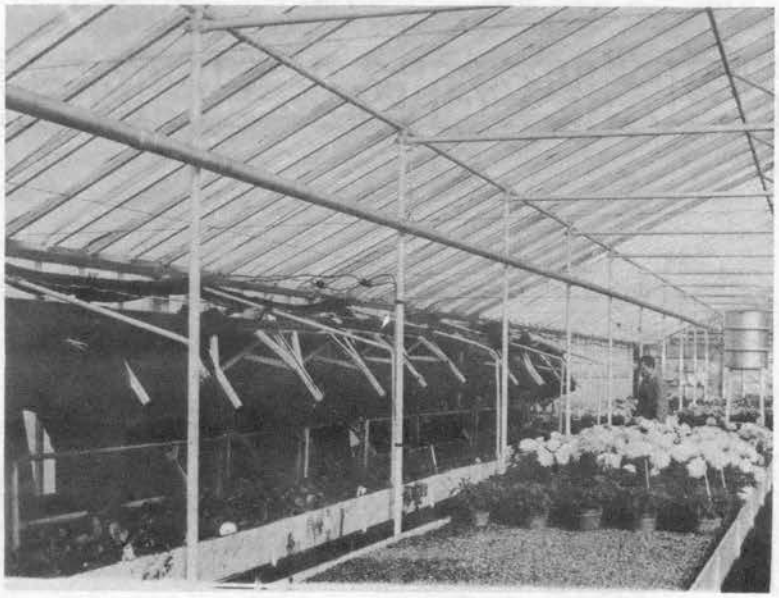


Figure 3. Fiberglass hoods opened for inspection. Showing the water mist system in operation.

with additional bulbs of various sizes to obtain as near to 14 footcandles as was practical (Table I). The incandescent bulbs were hung just above the fiberglass panels, one on each side of the gabled roof of the frame (Fig. 4). All plots received 8 1/2 hours of daylight each day. Supplemental light was supplied to one plot of each fiberglass covered frame for 3 hours each night, from 10:30 p.m. to 1:30 a.m. Light transmission was recorded with a Weston Sunlight Illumination Meter Model No. 756. Notations were made of the weather conditions existing at the time of the reading (Table I).

Four rooting mediums were used to make further comparisons of the rooting influences under each fiberglass plot. The four mediums were: (1) sand, (2) perlite, special grade #6, (3) sand and peat mixture, 1:1 by volume, and (4) perlite and peat, 1:1 by volume (Fig. 5).

The propagation bench arrangement, with the location of the rooting mediums and other factors of the experiment, is shown in Figure 6. An automatic intermittent mist system was used with one mist nozzle, centered 14 inches above the four rooting mediums of each plot (Fig. 3, 7). ROJT mist nozzles which deliver one gallon of water per hour at 40 p.s.i. were used. An electric clock turned the mist on each morning at 7:00 a.m. and off at 6:00 p.m. The frequency of the mist was controlled by an automatic electric cycle control unit which supplied 4 seconds of mist spray in each 6 minute period.

Bottom heat was supplied to the propagation bench by lead sheathed electric heating cables (Fig. 8). The temperature of the rooting medium was maintained at 72° F. by thermostat controls. The air temperature at night was approximately 60° F. in the greenhouse.

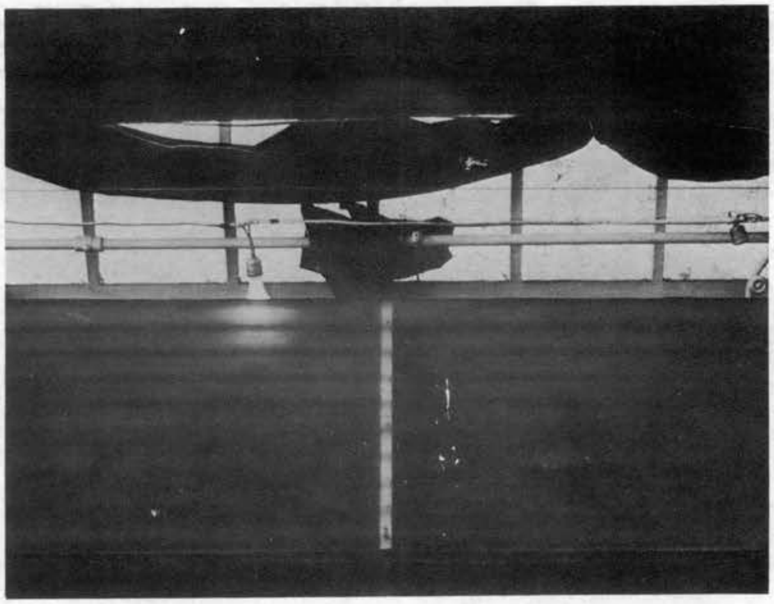


Figure 4. Supplemental lighting method. Lights were hung on each side of the gabled frame.

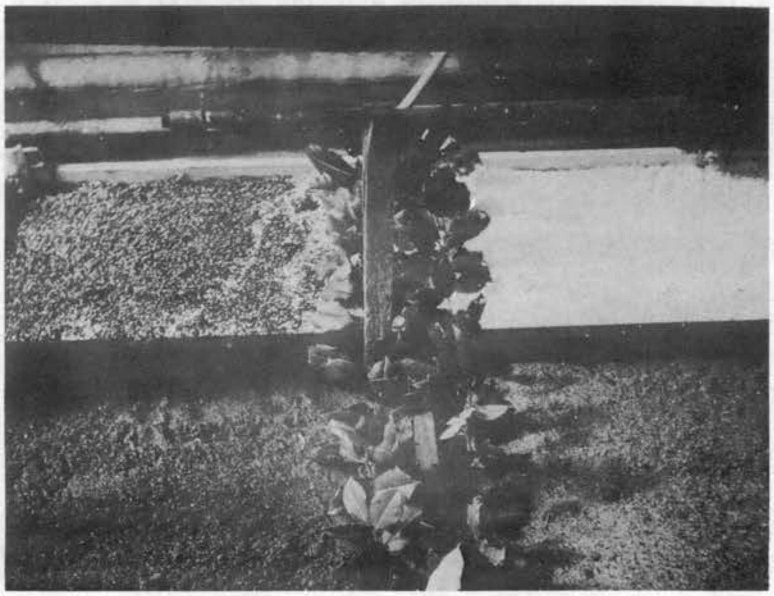
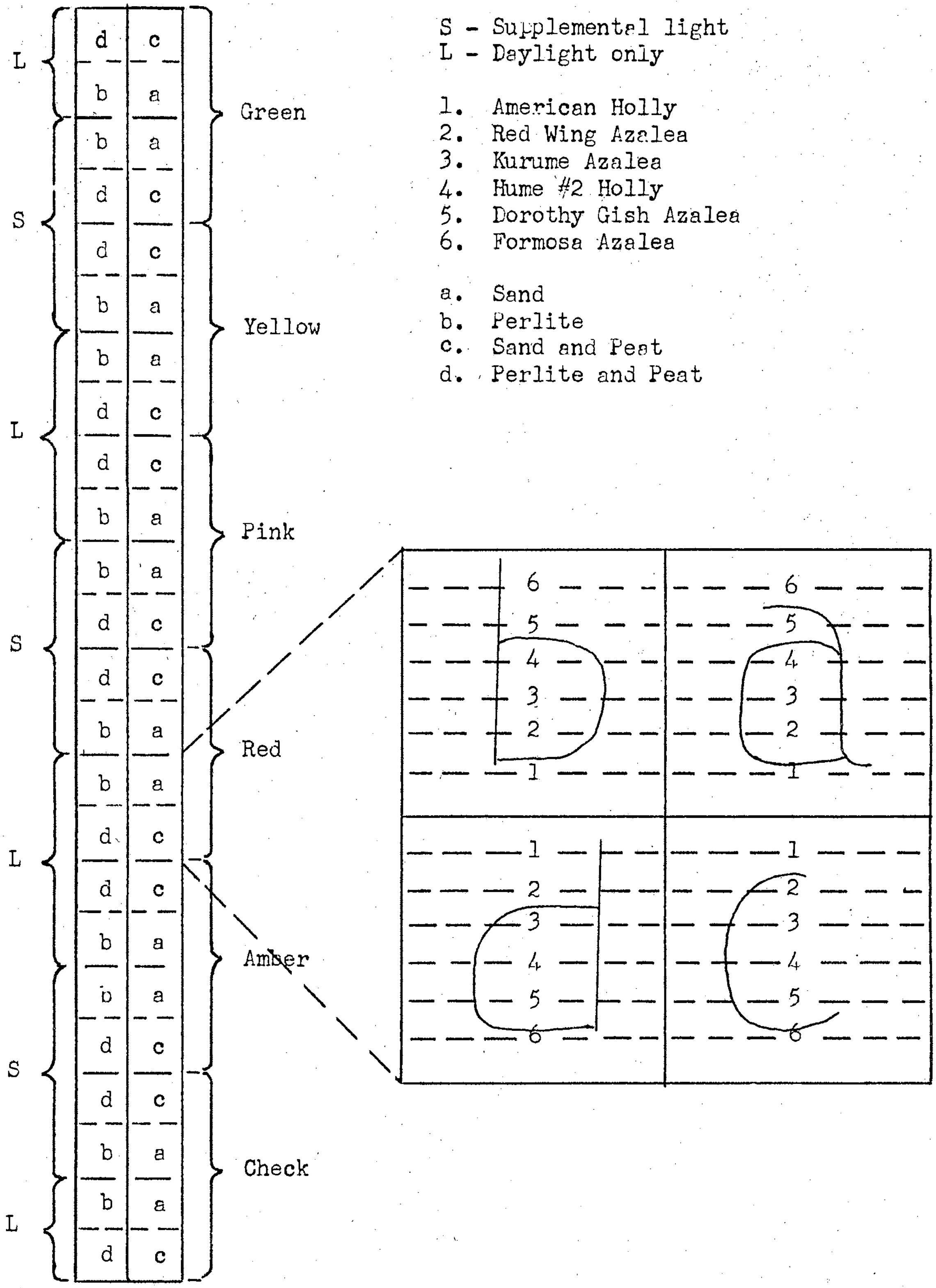


Figure 5. Rooting mediums. Upper, left to right perlite and peat, and perlite. Lower, sand and peat, and sand.



S - Supplemental light
L - Daylight only

1. American Holly
2. Red Wing Azalea
3. Kurume Azalea
4. Hume #2 Holly
5. Dorothy Gish Azalea
6. Formosa Azalea

a. Sand
b. Perlite
c. Sand and Peat
d. Perlite and Peat

Figure 6. Arrangement of propagation bench and placement of cuttings.

Figure 7. Mist system, medium and cutting arrangement.

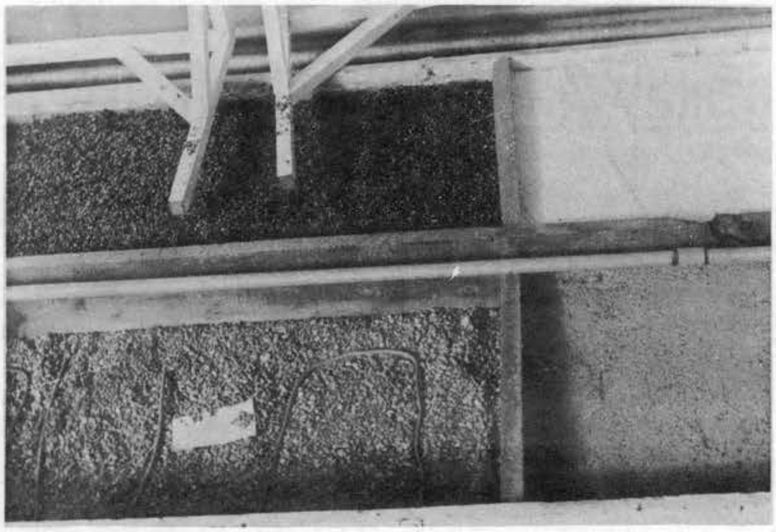


Figure 8. Electric heating cable arrangement and rooting mediums.

Cuttings of six plant materials from five locations were used (Table II). Kurume and Formosa azalea cuttings were taken from plants grown out of doors. Dorothy Gish and Redwing azalea cuttings were obtained from green house plants. American holly cuttings were obtained from native trees growing in southeastern Oklahoma woodlands and the Hume #2 holly cuttings from plants in a horticultural planting in Georgia. The cuttings were stuck, without hormone treatment, soon after they were received, as shown in Figure 7. From three to five leaves were left on each cutting and each was freshly wounded with a basal cut just prior to placement in the propagation bench.

Roots were rated from 0 to 5, for convenience in making rapid comparisons and in recording. This method of rating the rooting response of cuttings was evaluated by Mahlstede and Lana (36) and found to be accurate. The ratings used were as follows: 0 - no callus or root formation; 1 - callus and (or) the beginning of some root development; 2 - root growth totaling 1 1/2 inches or less; 3 - root growth totaling 1 1/2 to 3 inches; 4 - root growth totaling 3 to 6 inches; and 5 - total root growth of 6 inches or more.

EXPERIMENT B. Started January 23 and terminated March 18, 1960.

Cuttings of three plants were used in this experiment: Formosa Azalea, from Mississippi; American Holly, from Idabel, Oklahoma; and Dorothy Gish Azalea, from Guthrie, Oklahoma. These cuttings were prepared as in Experiment A except for the treatment of the fresh basal cut. The azaleas were treated with Hormodin #2 and the Holly with Hormodin #3 to assist in a more rapid rooting. The active ingredient in both Hormodin #2 and #3 was indolebutyric acid.

TABLE II

NAME, NUMBER AND SOURCE OF CUTTINGS USED

Common Name	Botanical Name	Cuttings Per Plot	Source
American Holly	Ilex opaca	10	Idabel, Oklahoma
American Holly	Ilex opaca H.V. Hume #2	10	Pine Mountain, Georgia
Kurume Azalea	Rhododendron obtusum	10	State College, Mississippi
Formosa Azalea	R. oldhamii	6	Lafayette, Louisiana
Redwing Azalea	R. indica obtusum	8	Guthrie, Oklahoma
Dorothy Gish Azalea	R. rutherfordiana	7	Guthrie, Oklahoma

EXPERIMENT C. Started May 11, 1960 and terminated July 20, 1960.

The colored fiberglass covered frames previously used in Experiments A and B were moved to a bench in another portion of the same greenhouse which was covered with glass. They were arranged in the same order as for the other experiments.

Potted plant materials were used in order to study the effects of the colored fiberglass on the growth of rooted plants and to obtain termperature data under the colored fiberglass. Each plot contained six plants each of geraniums, hydrangeas, Dorothy Gish Azalea, and Kurume Azalea in clay pots (Fig. 9).

Records were maintained of the air temperature, upper and lower leaf surface temperatures and soil temperature using a thermophil Elektron Thermometer, Type 4415 (Fig. 9). Growth and foliage conditions also were recorded.

A spectralanalysis of each of the colors of fiberglass (29) was made on a Beckman DK-1, Recording Spectrophotometer to determine the light quality transmission of the different fiberglass materials.

Figure 9. Thermophil Electron Thermometer, Type 4415, used for measuring temperature of the soil, leaf surface, and air. Plants are, left to right, Kurume Azalea, Dorothy Gish Azalea, hydrangea, and geranium.

CHAPTER IV

RESULTS

EXPERIMENT A.

In Table III are shown the overall root ratings obtained from each species over all rooting mediums and photoperiods under each color of fiberglass. The American Holly and the Redwing Azalea showed the greatest rooting response under the green, Kurume Azalea under the pink fiberglass, and the Hume #2 Holly and Formosa Azalea under the yellow fiberglass.

Table IV shows the rooting response as the percent of cuttings with a root rating of 3.0 or more. The overall average for each color shows the response was 80 percent greater in the check than under the red and 120 percent greater under the yellow than the red. The greenwood cuttings used in this experiment rooted better under yellow, green, and pink fiberglass than under the red and amber.

In Tables V and VI the rooting response obtained from colored fiberglass with 8 1/2 hours daylight and with an additional 3 hours of supplemental incandescent light in the middle of the night are given. The best overall rooting response was obtained under the green fiberglass with the 11 1/2 hour photoperiod. The best overall rooting with an 8 1/2 hour photoperiod was obtained under the yellow fiberglass.

The effects of rooting medium, photoperiod, and different colored fiberglass on the rooting of hollies and azaleas are given in Tables VII and VIII, respectively. When the rooting response under all fiberglass

TABLE III

THE EFFECT OF LIGHT, TRANSMITTED THROUGH FIVE DIFFERENT COLORS OF FIBERGLASS ON ROOTING OF GREENWOOD CUTTINGS. COMBINED RATINGS OF TWO PHOTOPERIODS (8½ and 11½ HOURS) AND FOUR ROOTING MEDIUMS (SAND, SAND AND PEAT, PERLITE, AND PERLITE AND PEAT). AVERAGE ROOT RATING (0 TO 5).*

	Color of Fiberglass					
Name	Green	Yellow	Pink	Red	Amber	Check
American Holly	1.80	1.70	1.53	0.55	0.45	0.59
Redwing Azalea	4.42	3.93	3.79	1.51	2.56	3.81
Kurume Azalea	4.17	4.62	4.68	2.68	3.37	4.30
Hume #2 Holly	2.41	3.13	2.86	1.73	1.65	2.03
Dorothy Gish Azalea	3.94	3.34	3.02	2.23	1.21	4.46
Formosa Azalea	3.82	4.24	3.72	2.55	3.23	1.97
Average per color	3.34	3.49	3.27	1.88	2.08	2.86

* Root rating: 5, high; 3, medium; 1, low; 0, none.

TABLE IV

THE EFFECT OF LIGHT TRANSMITTED THROUGH FIVE DIFFERENT COLORS OF FIBERGLASS ON THE PERCENT OF CUTTINGS WITH A ROOTING RATING OF 3.0* OR HIGHER. COMBINED RATINGS OF TWO PHOTOPERIODS (8½ AND 11½ HOURS) AND FOUR ROOTING MEDIUMS (SAND, SAND AND PEAT, PERLITE, AND PERLITE AND PEAT).

	Color of Fiberglass					
Name	Green	Yellow	Pink	Red	Amber	Check
American Holly	23.7	22.5	16.2	1.2	--	3.7
Redwing Azalea	87.5	78.1	73.1	19.7	43.7	73.4
Kurume Azalea	82.5	95.0	93.7	51.2	65.0	87.5
Hume #2 Holly	36.2	56.2	48.7	23.7	22.5	25.2
Dorothy Gish Azalea	71.4	57.2	48.2	39.3	12.5	85.7
Formosa Azalea	77.1	79.1	68.7	40.8	62.9	32.2
Average per color	63.1	64.7	58.1	29.3	34.4	51.6

* Cuttings rating 3.0 or better are considered sufficiently rooted to pot up and grow.

TABLE V

THE EFFECT OF PHOTOPERIOD AND COLOR OF FIBERGLASS ON ROOTING OF SELECTED GREENWOOD CUTTINGS. ROOT RATINGS (0 TO 5).

	11½ Hour Photoperiod						8½ Hour Photoperiod					
Common Name	Green	Yellow	Pink	Red	Amber	Check	Green	Yellow	Pink	Red	Amber	Check
American Holly	2.10	1.80	1.72	0.60	0.42	0.78	1.50	1.60	1.35	0.50	0.50	0.40
Redwing Azalea	4.50	3.64	4.39	1.72	2.77	3.55	4.35	4.22	3.19	1.30	2.36	4.07
Kurume Azalea	4.37	4.60	4.52	3.05	3.02	4.06	3.97	4.65	4.85	2.32	3.72	4.10
Hume #2 Holly	2.67	2.87	3.15	1.85	1.80	2.70	2.15	3.50	2.57	1.62	1.50	1.37
Dorothy Gish Azalea	4.22	3.58	3.30	3.47	1.30	4.30	3.67	3.10	2.75	1.00	1.12	4.62
Formosa Azalea	4.55	4.07	4.12	3.00	3.40	2.34	3.58	4.42	3.32	2.11	3.07	1.60
Color Average	3.73	3.34	3.53	2.28	2.11	3.05	3.20	3.58	3.00	1.47	2.04	2.69

TABLE VI

THE EFFECT OF PHOTOPERIOD AND COLOR OF FIBERGLASS ON ROOTING OF SELECTED GREENWOOD CUTTINGS. PERCENT OF CUTTINGS RATING 3.0 OR HIGHER.

	11½ Hour Photoperiod						8½ Hour Photoperiod					
Common Name	Green	Yellow	Pink	Red	Amber	Check	Green	Yellow	Pink	Red	Amber	Check
American Holly	30.0	22.5	20.5	2.5	--	5.0	17.5	22.5	12.5	--	--	2.5
Redwing Azalea	90.5	68.7	90.6	25.0	53.1	68.7	84.4	87.5	56.2	14.4	34.4	78.1
Kurume Azalea	87.5	95.0	92.5	60.0	57.5	90.0	77.5	95.0	95.0	42.5	72.5	85.0
Hume #2 Holly	40.0	47.5	57.5	25.0	27.5	37.5	32.5	65.0	40.0	22.5	17.5	15.0
Dorothy Gish Azalea	78.6	67.9	53.6	64.3	14.3	82.2	64.3	46.5	42.9	14.3	10.7	89.3
Formosa Azalea	87.5	74.9	79.1	58.3	66.6	41.6	66.6	83.3	58.3	33.3	59.3	24.9
Color Average	69.0	62.7	65.5	39.2	36.5	54.1	53.8	66.6	50.8	21.1	32.4	49.1

TABLE VII

THE EFFECT OF ROOTING MEDIUM, COLOR OF FIBERGLASS, AND PHOTOPERIOD ON THE ROOTING RESPONSE OF HOLLIES.
(ROOT RATING 0 TO 5)

	11½ Hour Photoperiod						8½ Hour Photoperiod					
Common Name	Green	Yellow	Pink	Red	Amber	Check	Green	Yellow	Pink	Red	Amber	Check
Sand	1.50	1.05	1.85	0.80	1.20	0.85	0.75	1.45	2.05	0.85	0.85	0.45
Perlite	1.35	1.85	1.45	0.75	0.85	1.45	1.35	1.70	1.40	0.85	0.80	0.75
Sand and Peat	2.85	3.10	2.65	0.45	0.60	1.70	1.60	3.55	1.30	0.45	0.45	0.75
Perlite and Peat	3.85	3.35	3.30	2.90	1.85	2.45	3.65	3.45	3.10	2.15	1.90	1.75
Color Average	2.39	2.34	2.31	1.22	1.12	1.61	1.84	2.54	1.96	1.08	1.00	0.92

TABLE VIII

THE EFFECT OF ROOTING MEDIUM, COLOR OF FIBERGLASS, AND PHOTOPERIOD ON THE ROOTING RESPONSE OF AZALEAS (ROOT RATING 0 TO 5)

	11½ Hour Photoperiod						8½ Hour Photoperiod					
Common Name	Green	Yellow	Pink	Red	Amber	Check	Green	Yellow	Pink	Red	Amber	Check
Sand	4.25	3.31	3.65	1.61	2.53	3.70	3.56	3.29	3.45	1.00	1.90	3.65
Perlite	3.79	2.91	4.22	2.57	2.47	2.82	3.57	3.76	3.85	1.84	2.75	2.67
Sand and Peat	4.62	5.00	4.10	3.00	1.59	3.92	3.88	4.60	2.82	1.40	2.67	3.57
Perlite and Peat	4.47	4.67	4.39	4.31	3.51	4.34	4.56	4.75	3.98	2.52	2.97	4.47
Color Average	4.35	3.97	4.09	2.87	2.55	3.69	3.89	4.10	3.53	1.69	2.57	3.59

colors with all species were combined (Table IX) the results were better in perlite and peat mix in both photoperiods. Slightly better rooting was obtained under green fiberglass in perlite and peat than under any other combination of fiberglass and rooting medium. When one considers only the rooting mediums and varieties the response is definitely higher in the perlite and peat than in either of the other mediums (Table X).

When only photoperiod and plant material are considered the 11 1/2 hour photoperiod showed a better rooting response for each variety than the shorter (8 1/2 hours) photoperiod (Table XI). Yellow fiberglass produced better rooting response in the 8 1/2 hour than in the 11 1/2 hour photoperiod. When rooting medium and photoperiod are combined the long photoperiod was found best with all four mediums.

EXPERIMENT B.

The results of this experiment are summarized in Table XII. Several changes were noticed in this experiment that evidently are the results of treating the cuttings witn Hormodin. American Holly and Formosa Azalea showed slightly better response to the long photoperiod. Dorothy Gish Azalea showed a higher response to the short photoperiod. The rooting response under the green, yellow and pink fiberglass and under the check was somewhat better with the long photoperiod. Under the red and amber colored fiberglass the response was better with the short photoperiod. The rooting in sand, perlite, and the perlite and peat mixture was better with the long photoperiod while the response in the sand and peat mixture was better with the short photoperiod.

TABLE IX

TOTAL EFFECTS OF ROOTING MEDIUM, COLORED FIBERGLASS, AND PHOTOPERIOD ON ALL THE CUTTINGS (ROOT RATING 0 TO 5)

	11½ Hour Photoperiod						8½ Hour Photoperiod					
Common Name	Green	Yellow	Pink	Red	Amber	Check	Green	Yellow	Pink	Red	Amber	Check
Sand	3.33	2.56	3.10	1.34	2.10	2.70	2.62	2.67	2.90	0.90	1.50	2.60
Perlite	2.97	2.53	3.30	1.93	1.90	2.35	2.83	3.12	3.10	1.52	2.10	2.10
Sand and Peat	4.00	4.30	3.40	2.15	1.26	3.20	3.12	4.25	2.30	1.10	1.90	2.60
Perlite and Peat	4.44	4.20	4.20	3.84	3.02	3.71	4.26	4.30	3.67	2.80	2.61	3.57

TABLE X

EFFECT OF ROOTING MEDIUM AND PHOTOPERIOD ON THE ROOTING OF CUTTINGS (ROOT RATING 0 TO 5)

	11½ Hour Photoperiod				8½ Hour Photoperiod			
	Sand	Perlite	Sand and Peat	Perlite and Peat	Sand	Perlite	Sand and Peat	Perlite and Peat
American Holly	1.00	0.65	1.50	1.80	0.90	0.60	1.00	1.40
Redwing Azalea	3.58	2.10	3.89	4.10	3.29	2.30	3.60	3.70
Kurume Azalea	3.90	4.00	4.00	4.30	3.05	4.10	3.70	4.60
Hume #2 Holly	1.40	1.90	2.10	4.10	1.20	1.70	1.70	3.85
Dorothy Gish Azalea	2.36	3.11	3.70	4.25	2.40	2.40	2.85	3.20
Formosa Azalea	3.00	3.30	3.30	4.64	2.50	3.24	2.10	3.93

TABLE XI

PHOTOPERIOD COMPARISONS WITH PLANT MATERIALS, COLOR OF FIBERGLASS, AND ROOTING MEDIUM. EXPERIMENT A. NOVEMBER 2, 1959 TO JANUARY 18, 1960.

	Photoperiod			Photoperiod			Photoperiod	
Plant Material	11½	8½	Fiberglass Color	11½	8½	Rooting Medium	11½	8½
American Holly	1.24	0.98	Green	3.73	3.20	Sand	2.54	2.22
Redwing Azalea	3.43	3.25	Yellow	3.34	3.58	Perlite	2.51	2.32
Kurume Azalea	4.04	3.93	Pink	3.53	3.00	Sand and Peat	3.08	2.49
Hume #2 Holly	2.50	2.15	Red	2.28	1.47	Perlite + Peat	3.70	3.44
Dorothy Gish Azalea	3.36	2.90	Amber	2.11	2.04			
Formosa Azalea	3.80	3.01	Check	3.05	2.69			

TABLE XII

PHOTOPERIOD COMPARISONS WITH PLANT MATERIALS, COLOR OF FIBERGLASS, AND ROOTING MEDIUM. EXPERIMENT B. JANUARY 23, 1960 TO MARCH 18, 1960.

	Photoperiod			Photoperiod			Photoperiod	
Plant Material	11½	8½	Fiberglass Color	11½	8½	Rooting Medium	11½	8½
American Holly	1.38	1.24	Green	2.27	2.51	Sand	2.78	2.51
Dorothy Gish Azalea	2.92	3.26	Yellow	2.62	2.04	Perlite	2.27	2.16
Formosa Azalea	1.49	1.42	Pink	2.32	2.07	Sand and Peat	1.20	1.30
			Red	1.57	1.97	Perlite + Peat	1.61	1.60
			Amber	1.00	1.84			
			Check	1.30	1.27			

EXPERIMENT C.

Table XIII gives a summary of the results obtained from Experiment C. The temperatures recorded showed a considerably higher air and leaf temperature under yellow than under amber and red fiberglass. Cloudy days produced little temperature variation between colors, however on partly cloudy days the temperature was 3 to 6 degrees higher under the yellow than under the amber fiberglass. On clear days there was a 10 to 12 degrees differential. The plant measurements do not show any particular trend except that the check plot has most of the high ratings but it also had the most leaf scorch and poor foliage color. The plants under the red and amber fiberglass were the darkest green and had the most attractive foliage. In hydrangeas a considerable amount of leaf scorch was noticed under all colors of fiberglass except red and amber.

Figure 10 shows the spectralanalysis results of all the colors of fiberglass. This spectralanalysis showed that all colors of the materials passed light of similar quality although the percent of transmission varied.

TABLE XIII

PLANT MEASUREMENT AND TEMPERATURE AVERAGES UNDER FIVE COLORS OF FIBERGLASS. EXPERIMENT C. MAY 11, 1960 TO JULY 20, 1960

	Plant Measurements					Temperatures F. **			
Fiberglass Color	Leaf Weight (gm/cm^2)	Plant Weight (grams)	Leaf Area (cm^2)	Stem Length (inches)	Leaf Color *	Air	Soil	Upper Leaf	Lower Leaf
Amber	.0400	40.5	452	4.7	5.7	89.7	89.5	93.5	91.5
Red	.0448	34.8	324	6.4	6.5	92.1	91.9	05.4	94.0
Pink	.0647	20.2	239	4.2	3.0	97.7	98.0	99.8	98.3
Yellow	.0485	24.3	319	4.4	3.3	99.6	96.7	100.0	97.5
Green	.0483	32.1	416	5.3	3.3	94.1	94.0	98.3	96.0
Check (glass)	.0533	47.2	599	7.4	2.9				

* Rated by a reflectometer manufactured by Photo-volt corporation using a tri-stimulus filter.

** Average of 21 air temperature and 11 soil and leaf temperature readings. All readings were made at 12:00 noon.

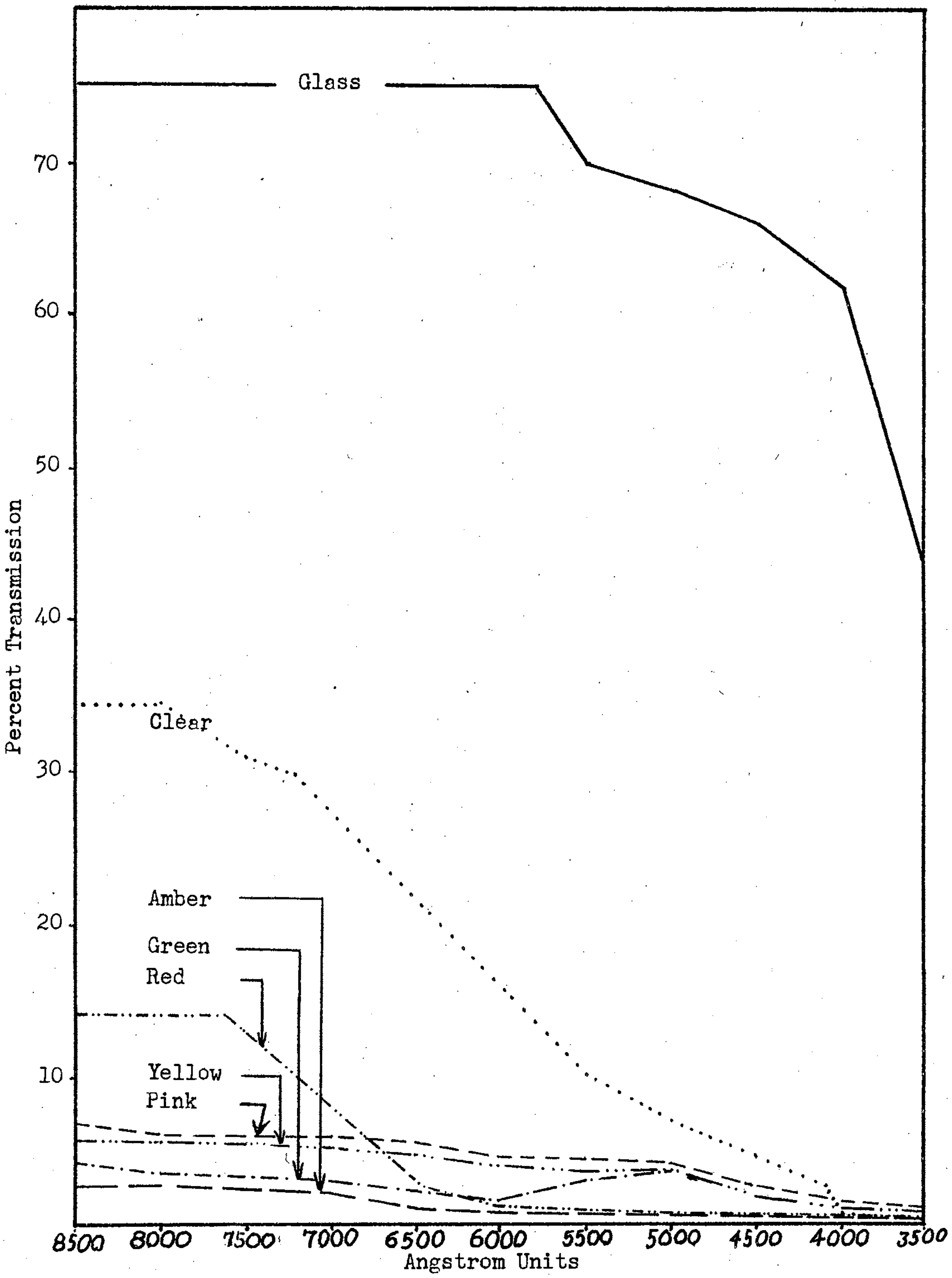


Figure 10. Spectralanalysis (Beckman DK-1 Recording Spectrophotometer) for fiberglass. Percent and quality of light transmission through green, yellow, pink, red, amber, and clear fiberglass and glass.

CHAPTER V

DISCUSSION

There have been many investigations concerning the influence of plant hormones and various internal factors on root formation in cuttings. However, there has been only occasional mention of the value of light quality (10, 46) on rooting of cuttings. Several workers (6, 9, 13 17, 30) have used various colors of cellophane and other materials for filters to obtain light of a given quality range. Based upon results of the preliminary trials with cellophane, this test was established with the thought that the red fiberglass panels would perhaps produce the greatest amount of rooting response. Red radiation has been shown to be the most efficient part of the spectrum in photoperiodic control of flowering (5). Downs, et al. (14), on the other hand, showed that far-red energy prevents stem elongation. It was assumed that the different colors of fiberglass would provide variations in light quality. A spectralanalysis of each of the colors of fiberglass (29) however, proved this assumption to be unfounded. In the spectrum covered by the analysis, 8500 Å to 3500 Å, each color of fiberglass had its highest percent of transmission at 8500 Å. The percent of transmission gradually decreased until at near 4000 Å practically all light was absorbed. Hendricks (23) indicated that the information obtained from the spectralanalysis very likely is not accurate due to the inability of the Beckman DK. 1, Recording Photometer to make compensation for the extreme dispersion of the light in the fiberglass by the many glass fibers.

The results shown in Table VI indicate that the rooting response of the cuttings vary considerably between the different colors. There seemed to be little correlation between color response of the two photoperiods.

When all varieties are considered together (Tables VI and VII) there is a definite improvement in the rooting response for long photoperiods. Hendricks (23) and Piringer (40) suggested that the photoperiod for this experiment might have been longer, perhaps as much as 16 to 18 hours, for good rooting response. They also suggested that it is very likely that the longer photoperiod would have a greater influence on the rooting response than the light color. The results of other workers (44, 54, 57, and 60) have shown that the use of 16 to 18 hour photoperiods, and in some species up to a 24 photoperiod, was best for rooting cuttings. Thus, it seems possible that longer photoperiods may produce even better results than the use of colored fiberglass.

The influence of the rooting medium was quite interesting. Without hormones, the perlite and peat mixture was best, however, when the cuttings were treated with indolebutyric acid, sand was better (Tables XI and XII).

The root system produced in the perlite and peat mixture was heavy and well branched, giving an excellent fibrous system for good potting results. The sand produced the next best root system, although it was not given the next highest rating. Perlite alone gave fair rooting results, but in many instances the callus developed to an excess and there was little or no root development.

Using the same mist cycle for all rooting mediums makes some difference in the rooting response. The conditions of this experiment with a four second mist period every six minutes seemed to be properly adjusted for sand and for the perlite and peat mixture. The perlite alone did not always appear to have sufficient moisture and the sand and peat mixture frequently had an excess of moisture.

Based upon these observations, it may be concluded that the reason for the improved rooting under the yellow and green colors, over the amber, during the cooler months was due in part to the higher air temperatures which prevailed under these colors. This is only an assumption, however, since the air temperatures in the chambers were not recorded during the winter.

The plant measurements of Table XIII do not show any particular trend except that the check plot shows several high ratings, but it had some of the poorest looking plants.

CHAPTER VI

CONCLUSIONS

Under the conditions of this experiment, it could be concluded that:

1. The response of species tested to light color (as obtained from fiberglass) and to rooting medium is offset, in part at least, by the application of root inducing hormones.
2. The rooting response of the individual plant species and varieties under fiberglass of the colors tested varied too greatly to establish a definite correlation between light quality and plant response.
3. Perlite and peat was an excellent rooting medium when no hormone was used to treat the cuttings.
4. Sand produced the best rooting response when root inducing hormones were used.

On the basis of this investigation it appears that future experiments should explore the following:

(1) Longer photoperiods and their effect on rooting response.

(2) The use of the colored fiberglass directly on a propagation house roof.

(3) Further investigation of the desirable foliage color and condition of pot plants grown under amber colored fiberglass.

CHAPTER VII

SUMMARY

Cuttings of four azaleas, from three states, and two American Hollies, from two states, were obtained for rooting tests under five colors of fiberglass, two photoperiods, and four rooting mediums. Moisture was supplied by an alternating water mist system with a cycle of four seconds mist applied in each six minute period. Temperature of the rooting medium was controlled with a lead covered electric heating cable with thermostats that maintained the temperature between 68° and 72° F.

Alsynite fiberglass panels of green, yellow, pink, red, and amber were used to cover the propagation bench. The spectralanalysis by the Oklahoma State Physics Laboratory indicated that these fiberglass colors transmitted similar qualities of light but the percent of transmission varied.

Each frame (color of fiberglass) was divided into two photoperiods one section receiving 8 1/2 hours of daylight and the other section receiving an additional three hours of supplemental light, supplied by incandescent bulbs in the middle of the night.

The four rooting mediums used were sand, perlite, sand and peat, and perlite and peat.

All untreated cuttings showed a better rooting response in the perlite and peat mixture. When hormones were used the rooting response was greatest in the sand.

Under the long photoperiod, when no hormone was used, all cuttings had a 10 to 14 percent better rooting response under all colors, than they did under the short photoperiod (natural daylight only). The effect of the various colors on rooting of different plant materials varied greatly, with the best responses being to green, yellow and pink. The response to red and amber was poor while the check was fair. The average response to the green fiberglass was the best under the long photoperiod and to the yellow in the short photoperiod.

The application of a rooting hormone appeared to reduce the rooting response to photoperiod under the conditions of this particular experiment.

Response of potted plants to the colored fiberglass was best under the amber and red and poorest under the yellow and pink. Hydrangeas did not scorch under the amber and red but did under the other four colors.

The air and soil temperatures during clear summer days were always highest under the yellow fiberglass. Under the red and amber fiberglass lowest soil and air temperature were recorded.

LITERATURE CITED

1. Anonymous. 1959. "How light controls plant development." Agri. Res. 8:3-5.

2. Audus, L. J. 1959. Plant Growth Substances. Leonard-Hill Books Ltd., London.

3. Avery, G., P. R. Burkholder, and H. B. Creighton. 1937. "Growth hormones in terminal shoots of Nicotiana in relation to light." Amer. Jour. Bot. 24:666-673.

4. Borthwick, H. A. and S. B. Hendricks. 1960. "Photoperiodism in plants." Sci. 32:1223-1228.

5. _______, _______, and M. W. Parker. 1952. "The reaction controlling floral initiation." Proc. Nat. Acad. Sci. 38:929-934.

6. _______, _______, E. H. Toole, and V. K. Toole. 1954. "Action of light on lettuce seed germination." Bot. Gaz. 115(3):205-225.

7. _______, and M. W. Parker. 1952. "Light in relation to flowering and vegetative development." Rept. Thirteenth International Hort. Cong. London. Pages 801-810.

8. _______, _______, and S. B. Hendricks. 1948. "Wavelength dependence and nature of photoperiodism." Lotsya. 1:71-78.

9. _______, _______, _______. 1948. "Action spectrum for photoperiodic control of floral initiation of long-day plants, winter barley (Hordeum vulgare)." Bot. Gaz. 110:103-118.

10. Chadwick, L. C. 1949. "Some results with the use of opaque structures for propagation of cuttings." Proc. Amer. Soc. Hort. Sci. 53:567-572.

11. Christensen, E. 1954. "Root production in plants following localized stem irradiation." Sci. 119:127-128.

12. Crocker, W. 1936. "Effect of the visible spectrum upon germination of seeds and fruit." Duggar, Biological Effects of Radiation. 1:791-828. McGraw-Hill, New York.

13. Downs, R. J., H. A. Borthwick, and A. A. Piringer. 1958. "Comparison of incandescent and fluorescent lamps for lengthening photoperiods." Proc. Amer. Soc. Hort. Sci. 71:568-578.

14. ______, S. B. Hendricks, and H. A. Borthwick. 1957. "Photoreversible control of elongation of pinto beans and other plants under normal conditions of growth." Bot. Gaz. 118:119-208.

15. Fischer, C. C., F. B. Widmoyer, and D. P. Watson. 1956. "Effect of various wavelengths of light on selected ornamental plants." Mich. State Quar. Bul. 39(2):259-262.

16. Flint, L. H. 1934. "Light in relation to dormancy and germination of lettuce seed." Sci. 80:38-40.

17. ______, and E. D. McAlister. 1935. "Wavelengths of radiation in the visible spectrum inhibiting the germination of light-sensitive lettuce seed." Smith. Misc. Coll. 94(5):1-11.

18. Garner, W. W., and H. A. Allard. 1920. "Effect of relative length of day and night and other factors of environment on growth and reproduction." Jour. Agr. Res. 18:553-606.

19. ______, ______. 1931. "Effects of abnormally long alternations of light and darkness on growth and development of plants." Jour. Agr. Res. 42(10):629-651.

20. Hanchey, R. H. 1955. "Effects of fluorescent and natural light on vegetative and reproductive growth in Saintpaulia." Proc. Amer. Soc. Hort. Sci. 66:378-382.

21. Hartman, H. T., and D. E. Kester. 1959. Plant Propagation Principles and Practices. Prentice-Hall, Englewood Cliffs, New Jersey.

22. ______, and J. E. Whisler. 1956. "Rooting cuttings under mist." Calif. Agr. 10:7, 12.

23. Hendricks, S. B. 1960. Plant physiologist, USDA Agricultural Research Center, Beltsville, Maryland. Personal conversation.

24. Hess, C. E. 1956. "The theory of mist propagation." Amer. Nurs. 104(4):15-16.

25. ______, and W. E. Snyder. 1954. "Interrupted mist found superior to constant mist in tests with cuttings." Amer. Nurs. 100(12):11-12, 82.

26. Hitchcock, A. E. 1928. "Effect of peat moss and sand on rooting response of cuttings." Bot. Gaz. 86:121-148.

27. Holly, W. D. 1960. "Effects of light manipulation, carbon dioxide on plant life." Florists Rev. 126:16, 43-56.

28. Hull, Ansel L. 1956. "Industrial and commercial landscape design in Oklahoma." Masters Thesis. Oklahoma State University.

29. Hurt, James. 1960. "Report on spectral analysis of colored fiberglass." Physics Dept., Oklahoma State University.

30. Kincaid, R. H. 1935. "Effects of certain environmental factors on germination of Florida cigar wrapper tobacco seed." Fla. Agr. Expt. Sta. Bul. 277.

31. Kranz, F. L., and J. L. Kranz. 1957. Gardening Indoors Under Lights.

32. Krume. J. B. 1959. "Report of spectralanalysis of flat colored 'Alsynite' Fiberglass." Physics Dept., Oklahoma State University.

33. Laurie, A., and V. H. Ries. 1950. Floriculture: Fundamentals and Practices. McGraw-Hill. New York. 2nd Ed.

34. Lloyd, F. E. 1924. "The fluorescent colors of plants." Sci. 59:241-248.

35. Mahlstede, J. P., and E. S. Haber. 1957. Plant Propagation. Wiley and Sons Inc. New York.

36. ______, and E. P. Lana. 1958. "Evaluation of the rooting response of cuttings by method of ranks." Proc. Amer. Soc. Hort. Sci. 71:585-590.

37. Maximov, N. A. 1938. Plant Physiology. McGraw-Hill. New York.

38. Meyer, B. S., D. B. Anderson, and R. H. Bohning. 1960. Introduction to Plant Physiology. Van Nostrand Co. Inc. New York.

39. Parker, M. W., S. B. Hendricks, H. A. Borthwick, and N. J. Scully. 1946. "Action spectrum for photoperiodic control of floral initiation of short day plants." Bot. Gaz. 108:1-26.

40. Piringer, A. A. 1960. Plant physiologist, USDA Agricultural Research Center, Beltsville, Maryland. Personal communication.

41. Schultz, Peggie. 1955. Growing Plants Under Artificial Lights. M. Barrows Co. New York.

42. Shirley, H. L. 1929. "The influence of light intensity and light quality upon the growth of plants." Amer. Jour. Bot. 16:354-390.

43. Skinner, H. T. 1940. "Further observations on the propagation of rhododendrons and azaleas by stem and leaf bud cuttings." Proc. Amer. Hort. Sci. 37:1013-1018.

44. Snyder, W. E. 1955. "Effects of photoperiod on cuttings of Taxus cuspidata while in the propagation bench and during the first growing season." Proc. Amer. Soc. Hort. Sci. 66:397-402.

45. Stoutemyer, V. T., and A. W. Close. 1946. "Plant propagation under fluorescent lamps." U. S. Dept. Agr. Bur. Plant Ind. leaflet.

46. _______, _______. 1946. "Rooting cuttings and germinating seed under fluorescent and cold cathode lighting." Proc. Amer. Soc. Hort. Sci. 48:309-325.

47. _______, _______. 1947. "Changes of rooting response in cuttings following exposure of the stockplants to light of different qualities." Proc. Amer. Soc. Hort. Sci. 49:392-394.

48. _______, _______, and F. L. O'Rourke. 1945. "Rooting greenwood cuttings without sunlight under fluorescent lamps." Sci. 101:546.

49. Strain, H. H. 1944. "Chloroplast pigments." Ann. Rev. Biochem. 13:591-610.

50. Toole, E. H., V. K. Toole, H. A. Borthwick, and S. B. Hendricks. 1955. "Interaction of temperature and light in germination of seeds." Plant Physiol. 30(5):473-478.

51. Van der Veen, R., and G. Meijer. 1959. Light and Plant Growth. MacMillan Book Co. New York.

52. Wassink, E. C., and J. A. J. Stolwijk. 1956. "Effects of light quality on plant growth." Ann. Rev. Plant Physiol. 7:373-400.

53. Waxman, S. 1958. "Light treatment in the propagation of woody plants." Plants and Gardens. 14:282-284.

54. _______. 1960. "Flash-lighting of chrysanthemum and weigela." Rept. to 57th Ann. Mtg. Amer. Soc. Hort. Sci., Stillwater, Okla.

55. _______, and J. P. Nitsch. 1956. "Influence of light on plant growth." Amer. Nurs. 104(10):11-12.

56. Withrow, A. P. 1947. "Response of China aster to method of day length extension." Proc. Amer. Soc. Hort. Sci. 49:405-409.

57. _______. 1948. "Artificial lighting for forcing greenhouse crops." Indiana Agr. Expt. Sta. Bul. No. 533.

58. _______, and R. B. Withrow. 1947. "Plant growth with artificial light sources of radiant energy." Plant Physiol. 22:494-513.

59. Yerkes, G. E. 1945. "Propagation of trees and shrubs." U. S. Dept. Agr. Farmers Bul. 1567.

60. Zimmerman, P. W., and A. E. Hitchcock. 1929. "Vegetative propagation of holly." Cont. Boyce Thomp. Inst. 2:205-219.

61. Zscheile, F. P., and C. L. Comar. "Influence of preparation procedures on the purity of chlorophyll compounds as shown by absorption spectra." Bot. Gaz. 102:463-481.

VITA

Hugh Kenneth Hedger

Candidate for the Degree of

Master of Science

Thesis: THE ROOTING RESPONSE OF SELECTED PLANTS AS INFLUENCED BY LIGHT QUALITY AND ROOTING MEDIUMS

Major Field: Ornamental Horticulture

Biographical:

Personal Data: Born near Idabel, Oklahoma, January 18, 1920, the son of Howard R. and Alice Kara Hedger.

Education: Attended grade school and high school at Idabel, Oklahoma; graduated from Idabel High School in 1939; received the Bachelor of Science degree from the Oklahoma State University, with a major in Horticulture, in August, 1947, completed requirements for the Master of Science degree in May, 1961.

Professional experience: Lived on a fruit and vegetable farm; served in the U. S. Air Force during World War II (1942-1945); taught Veterans Agricultural Training at Cleveland, Oklahoma, for two years; assistant County Agent in Tulsa County Oklahoma, for four years; employed four years by the Oklahoma State University Foreign Aid contract program in Ethiopia as a staff member in the Department of Horticulture of the Imperial Ethiopian College of Agriculture.